U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-298 459

Guidance for Selecting TSP Episode Monitoring Methods

(U.S.) Environmental Protection Agency, Research Triangle Park, NC

12 Feb 79

PB 298459

United States
Environmental Protection
Agency

Office of [illegible]lity
Planning [illegible] Standards
Research Triangle Park NC 27711

EPA-450/4-79-007
OAQPS No. 1.2-114
February 1979

Air

EPA

Guideline Series

Guidance for Selecting TSP Episode Monitoring Methods

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NATIONAL TECHNICAL
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U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. OAQPS 1.2-114	2.
3. RECIPIENT'S ACCESSION NO. PB298459	
4. TITLE AND SUBTITLE: Guidance for Selecting TSP Episode Monitoring Methods	5. REPORT DATE: Feb. 12, 1979
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): George Manire	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Environmental Protection Agency, Monitoring & Reports Branch, Monitoring Section, Monitoring & Data Analysis Div.	10. PROGRAM ELEMENT NO. 2AD889
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: Office of Air, Noise, & Radiation, Office of Air Quality Planning & Standards, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This guideline explains the principles of operation of the two episode particulate monitoring methods which are modification of the reference method and the procedures for establishing a site and season-specific relationship between the high volume method and particulate methods other than the modified reference methods.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Episode monitoring	site-season relationship	

18. DISTRIBUTION STATEMENT: release to RO, state and local agencies	19. SECURITY CLASS *(This Report)*: unclassified	21. NO. OF PAGES: 34
	20. SECURITY CLASS *(This page)*: unclassified	22. PRICE: PC A03/MF A01

EPA Form 2220-1 (9-73)

EPA-450/4-79-007
(OAQPS No. 1.2-114)

Guidance for Selecting TSP Episode Monitoring Methods

Monitoring and Data Analysis Division
Office of Air Quality Planning and Standards
and
Environmental Monitoring and Support Laboratory
Office of Research and Development

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

February 1979

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Publication No. EPA-450/4-79-007

(OAQPS No. 1.2-114)

PREFACE

The Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Sampler Method) specifies a twenty-four hour sampling interval. However, the use of particulate monitors which provide data at much shorter time intervals than twenty four hours is necessary during air pollution episodes and for purposes of daily reporting of an index of air quality. As a result, revised monitoring regulations have been proposed (Appendix C of 40 CFR 58, Aug. 7, 1978) that allow the use of short term particulate monitors. Consequently, this guideline was prepared to describe the two modified versions of the Reference Method for Particulates that are permitted to be used during air pollution episodes and for purposes of daily air quality index reporting. In addition, the guideline explains the procedure for establishing a site and season-specific relationship between the high volume method and particulate methods other than the two modified high volume methods. Criteria are included in this guideline for use by Regional Offices, State,and local agencies in determining if such a relationship is satisfactory for use during particulate episodes. Example calculations showing the detailed steps are also included.

ACKNOWLEDGMENT

This guideline is based on a report furnished to the Environmental Protection Agency by Frank Smith of the Research Triangle Institute, Research Triangle Park, North Carolina in fulfillment of a project assignment under Contract No. 68-02-2714. Through the primary efforts of George Manire of the Monitoring and Reports Branch, Monitoring and Data Analysis Division, Office of Air Quality Planning and Standards, Environmental Protection Agency, the report was reviewed and rewritten in guideline series format. Technical assistance and review were provided by Alan Hoffman, William Cox, and Stanley Sleva of the Office of Air Quality Planning and Standards and Frank McElroy and Larry Purdue of the Environmental Monitoring and Support Laboratory, Research Triangle Park.

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GUIDANCE FOR SELECTING TSP EPISODE MONITORING METHODS

I. INTRODUCTION

The EPA requirements which are prescribed in Title 40 Code of Federal Regulations (40 CFR) Part 51 for ambient air quality monitoring for purposes of State Implementation Plans (SIPs) are being revised. The revised requirements will appear in a new Part 58 entitled, "Ambient Air Quality Surveillance," and will include revisions to the emergency episode monitoring requirements now described in 40 CFR Part 51.17(c). The emergency episode guidance provided in Federal Regulation Part 51.16 and Appendix L will be amended to reflect the new requirements. The new regulations would permit the use of two modified versions of Appendix B of 40 CFR, Part 50 - Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method). The regulations will also permit the use of non high-volume methods provided that specific site relationships to the reference method have been determined and documented and that these methods provide for short-term measurements.

A. Purpose and Scope

There are two purposes for this guideline. The first is to explain the principles of operation of the two episode particulate monitoring methods which are modifications of the reference method: (1) high-volume sampling over short sampling time intervals; and (2) staggered high-volume sampling. These methods may be used by an agency in their TSP episode network without further testing in most cases.

Secondly, a procedure is described for establishing a site- and season-specific relationship between the high-volume method and particulate methods other than the two mentioned above.

This guideline does not cover the criteria for emergency episode station location or design, sampling frequency, mechanics of becoming aware of an episode, or corrective actions to take in order to minimize episodic conditions.

B. Rationale for the Revised Episode Regulations

When the requirements described in 40 CFR Part 51.16 and 51.17(e) were promulgated, tape samplers were required in order to monitor the ambient air during total suspended particulates (TSP) episodes as a basis for initiating episode control actions. The tape sampler provided more frequent measurements at shorter time intervals then the reference method.

Since the promulgation of this regulation, several investigations have attempted to establish a relationship between the TSP as measured by the reference method in air and the optical density or reflectance of particulate matter collected on paper spots or tapes[1-16]. All such studies have shown that the relationship is dependent on a number of factors which preclude the method's general application as an index of TSP mass concentration. The optical density, transmittance, or reflectance of the spot sample is proportional to mass concentration only when the optical properties of the aerosol (e.g., particle size, shape, density, refractive index, color, size distribution, etc.) remain reasonably constant.

Several area- and site-specific empirical relationships of mass concentration to reflectance or optical density have been calculated. Both linear[3,5,13-16] and non-linear[3,4,7-11] relationships have been reported as suitable for specific sites and conditions. However, there appears to be no universally consistent relationship between the tape sampler and the hi-vol sampler measurements.

Because of this problem, the emergency episode monitoring requirements are being revised by allowing the use of two modified reference methods; by requiring that a specific site relationship be determined for methods not based on the reference method (such as the tape sampler) and by removing the specification in coefficient of haze (COH) for tape samplers from §51.16 and Appendix L of 40 CFR Part 51.

II. USE OF MODIFIED REFERENCE METHODS

Short-time interval high-volume sampling and staggered high-volume sampling are two acceptable episode monitoring methods. Because these methods are based on the reference method, it is believed that they are applicable as monitoring methods during an episode without having to determine a specific site relationship. In areas where there is high humidity, oily particulate, acidic particulate, or types of particulates for which equilibration is not achieved in 2 hours, an agency should establish a specific site relationship between the recommended methods and the referenced hi-vol method. However, in most cases, the recommended methods can be used without testing.

A. Short-Time Interval High Volume Sampling

The complete procedure for short-time interval high-volume sampling is given in Appendix A, however, the major modifications are: (a) a shorter sampling period (4 hours), and (b) different filter equilibration conditions (2 hours).

The method is applicable to measurement of TSP concentrations in ambient air during air pollution episode conditions, using a 4-hour sampling period and a 2 hour filter equilibration period. That is, every 4 hours the loaded filter is replaced by a clean filter. Thus, data are available 6 hours after the start of the sampling. This method requires only one sampler; however, it may be wise to have a second one in case the first one fails during an episode. TSP values representing 4 hour averages for successive sampling periods may be plotted or tabulated as they are received in a fashion to facilitate the detection of a change in the ambient TSP conditions.

Based on a coefficient of variation (relative standard deviation) of approximately 5% for this method, successive differences of less than 10% should not be interpreted as a significant change. However, four or more TSP values, from successive sampling periods, changing in the same direction should be interpreted as a trend.

The disadvantages of this method over the staggered high-volume sampling are:

(a) Because acid gases affect a surface reaction on alkaline filters and because six filters are needed to determine a 24-hour TSP level, this method of monitoring an episode could introduce a larger bias in the TSP analysis;

(b) Because the filters have to be changed and the air flow rate measured every four hours, beginning four hours after the first hour, there will be a greater chance for human error. However, based on a short-term interval high-volume sampling study[1], the established relative standard deviation (coefficient of variation) for single operator (same sample, different samplers, and different day) variation for four hour sampling and two hour equilibration periods is only 5.2 percent; and

(c) Because the filter has to be changed every four hours, the 24-hour TSP ($\mu g/m^3$) values will be the average of six intermittent TSP ($\mu g/m^3$) values, thus not a true continuous 24-hr value.

The advantages of this method over the staggered high-volume sampling are:

(a) Provides a measure of the TSP over a very recent (four hour) period of time; thus as a result, concentrations are available 6 hours after the start of sampling;

(b) Only one sampler is required, however, a second one is recommended;

(c) A lower probability that dense fog, high humidity, oily particulate, or excessive particulates collected during an episode will severely reduce the air flow through the filter, which may reduce the precision and accuracy of this method; and

(d) The two hour equilibration may be more effective on a four hour TSP sample than on a 24-hour TSP sampler.

B. Staggered High-Volume Sampling

This method is based upon the reference method modified such that multiple monitors are used at the site and the filters are weighed after 2 hours of equilibration, as described in Appendix A, 7.2. The starting time of each high-volume monitor is staggered by some constant time interval. For example, staggering the starting time of each monitor by 4 hours would require 6 monitors for continuous operation and would provide a 24-hour TSP average value, after the first 26 hours and every 4 hours thereafter.

This method can be implemented with any desired time increment between sampling start times. However, due to the number of samplers required, increments of less than four hours would probably not be practical.

The samplers should be placed on-site in a matrix such that they will be sampling the same atmosphere but without interference with each other. The electrical power supply should be capable of supporting the total number of samplers operating simultaneously without varying appreciably in voltage as individual samplers are taken off or put on line.

TSP values representing 24 hour averages for successive sampling periods may be plotted or tabulated as they are recieved in a fashion to facilitate the detection of a change in the ambient TSP conditions.

Based on a coefficient of variation of 3.7 percent for the reference method, successive differences less than about 7.4% should not be interpreted as a significant change. However, four or more TSP values, from successive sampling periods, changing in the same direction should be interpreted as a trend.

The disadvantages of staggered high-volume sampling as compared to the short-time interval high-volume sampling include:

(a) Increased equipment, power and labor requirements;

(b) The elapsed time from the start of sampling until the first results are available is 26 hours;

(c) The high probability that dense fog, high humidity, oily particulate, and excessive particulates collected during an episode may severely reduce the air flow through

the filter, thus reducing the precision and accuracy of this method; and

(d) A 2 hour equilibration time may not be long enough to account for moisture on the 24-hour sample.

Advantages of using staggered high-volume sampling over the short-time interval high-volume sampling are:

(a) It measures for 24 hours, thus the results should be a better indicator of the 24-hour TSP level; and

(b) It provides current 24-hour TSP behavior during an episode condition.

III. USE OF OTHER METHODS

Whenever a method other than the two recommended methods is to be used for episode monitoring, a specific site relationship between it and the reference hi-vol method must be established and documented.

The disadvantage of using other methods over the recommended methods is that the recommended methods are based on the same principle as the reference method and in most cases, the specific site relationship need not be determined, thus reducing the testing time, testing cost, and the need perhaps for skilled personnel or expensive equipment.

The advantage of other methods over the recommended methods may be the advantage of automation which could minimize the loss of time between air samples and important strategy decisions.

This section describes the procedures which should be followed to develop the specific site relationship.

A. Test Conditions for Establishing the Relationship

The reference method is the Federal Register hi-vol reference method and should be operated according to the method specification except that the sampler need not be operated from midnight to midnight, any given 24 hours of continuous operation is acceptable. The method (candidate method) for which the specific site relationship is to be established should be

operated and calibrated, if needed, according to the applicable operation manuals.

At least ten (10) ambient air measurements should be made simultaneously by the candidate and the reference hi-vol methods. The air samples should be taken simultaneously in the same area (i.e., within 2-3 meters of each other) without interference between samples or instruments.

These measurements should be made on ambient air containing TSP concentrations in the range that the candidate method will be subjected to during an episode. To accomplish this, the measurements could initially be performed in non-episodic (normal) atmospheric conditions, to establish the relationship, but resumed during an episode to determine if the established relationship changes significantly. The relationship may be a function of the pollutant source, such as coal combustion, dust storms, or fuels used. If such is the case, then that particular pollutant source specific relationship should be used.

If the candidate method has a shorter measuring time interval than the reference hi-vol method, a sufficient number of sequential interval measurements should be made to equal the time period of the reference hi-vol method. The TSP concentration as determined by the reference hi-vol method and the TSP concentration determined by the candidate method (or the mean of sequential determinations by the candidate method) are considered a "test pair."

All records, test data, procedural description and details, and other documentation obtained from (or pertinent to) tests made for the purpose of testing a candidate method should be identified, dated, and signed by the testor.

B. Evaluation Procedure

The test pairs are used to estimate the functional relationship between the candidate and the reference methods. Graphical or regression techniques are useful in estimating the form of the regression equation between the candidate method (y) and the reference hi-vol method (x). If the relationship appears to be reasonably linear

over the range of interest; then, standard linear regression techniques can be used to estimate and test the significance of the relationship. Appendix B contains a worksheet which illustrates the basic calculations when a linear relationship appears suitable. Agencies are not advised to use a candidate method whenever the linear coefficient of correlation is less than 0.7.

These calculations are based on the assumption that measurements obtained using the reference method have little measurement error compared to measurements errors in the candidate method. Thus, the reference method is treated as the independent variable (X) in estimating the least squares regression line which relates the two measurements. Other estimation techniques[18,19] are available for situations where both variables are subject to substantial errors.

C. Other Relationships

In cases where the relationship does not appear to be linear over the entire range of interest, other techniques for relating the two measuring systems may be used. For example, some agencies[5] have found that a piece-wise linear function is superior to a single linear function. Tests of significance are not as straightforward as for the linear case and require care in interpretation. Often, it is possible to linearize a non-linear relationship by transformation of variables (e.g., $\sqrt{X}$, log X, etc). In such cases, the procedures outlined in Appendix B may be applied to the transformed variables. In some rare cases, it may be necessary to use non-linear regression techniques[17] to properly fit the measured data.

D. Methods for Displaying the Relationship

Because of the need to quickly assess the quality of the ambient air during a TSP episode, it is recommended that a method be devised to aid in the rapid interpretation of the data. Methods such as the use of a graph, table of corresponding values, or the equation of the relationship could be used to obtain a rapid interpretation of the data. In any event, regardless of the method chosen, it should be readily accessible to the instrument operator or data user.

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APPENDIX A

METHOD FOR THE DETERMINATION OF TOTAL SUSPENDED PARTICULATES IN THE ATMOSPHERE OVER SHORT SAMPLING TIMES, (HIGH VOLUME METHOD)

APPENDIX A
METHOD FOR THE DETERMINATION OF TOTAL SUSPENDED PARTICULATES IN THE ATMOSPHERE OVER SHORT SAMPLING TIMES. (HIGH VOLUME METHOD)

1.0 PRINCIPLE AND APPLICABILITY

1. Air is drawn into a covered housing and through a filter by means of a high-flow-rate blower at a flow rate (1.70 to 1.98 m^3/min; 60 to 70 ft^3/min) that allows suspended particles having diameters of less than 100 µm (Stokes equivalent diameter) to pass to the filter surface (ref. 1). Particles within the size range of 0.1 to 100 µm diameter are ordinarily collected on fiberglass filters. The mass concentration of total suspended particulates in the ambient air (µg/m^3) is computed by measuring the mass of collected particulates and the volume of air sampled.

2. This method is applicable to measurement of 4-hour average mass concentrations of total suspended particulates in ambient air. To assure measurements of acceptable precision, this method should not be used to measure average concentrations of less than about 30 µg/m^3 (this yields 4-hour samples of approximately 20 mg). The size of the sample collected is usually adequate for other analyses. Concentrations as low as 10 µg/m^3 can be measured; however, the relative error would probably be larger than that given in section 4.0.

2.0 RANGE AND SENSITIVITY

Weights are determined to the nearest 0.1 mg, airflow rates are determined to the nearest 0.1 m^3/min, times are determined to the nearest minute, and mass concentrations are reported to three significant digits, e.g., 102 µg/m^3 and 50.6 µg/m^3.

3.0 INTERFERENCES

1. Particulate matter that is oily, such as photochemical smog or wood smoke, may block the filter and cause a rapid drop in airflow at a nonuniform rate. Dense fog or high humidity in conjunction with certain types of particulates may severely reduce the airflow through the filter.

2. Fiberglass filters are comparatively insensitive to changes in relative humidity but collected particulates can be hygroscopic (ref. 2).

3. Acid gases in the sample air may be converted to particulate matter on the surface of alkaline filters (refs. 3, 4).

4.0 PRECISION, ACCURACY, AND STABILITY

4.1 Precision

Based on the Short-term High Volume Study, the estimated relative standard deviation (coefficient of variation) for single operator (same sample, different samplers, and different day) variation for 4-hour sampling and 2-hour equilibration periods is 5.2 percent.

4.2 Accuracy

The accuracy with which the sampler measures the true average concentration cannot be quantitatively determined. Measured values higher than the true values may result when alkaline filters are used. A functional analysis of the method indicates that other large biases should not normally occur in short-term sampling (ref. 5).

5.0 APPARATUS

5.1 Sampling

5.1.1 Sampler. The sampler consists of three units: 1) the faceplate and gasket, 2) the filter adapter assembly, and 3) the motor unit. Figure A-1 shows an exploded view of these parts, their relationship to each other, and how they are assembled. The sampler must be capable of passing environmental air through a 406.5 cm^2 (63 $in.^2$) portion of a clean 20.3 by 25.4 cm (8 by 10 in.) fiberglass filter at a rate of at least 1.70 m^3/min (60 ft^3/min). The motor must be capable of continuous operation for 4-hour periods with input voltages ranging from 110 to 120 volts, 50-60 cycles alternating current and must have third-wire safety ground. The housing for the motor unit may be of any convenient construction so long as the unit remains airtight and leak free.

5.1.2 Sampler Shelter. It is important that the sampler be properly installed in a suitable shelter. The shelter is subjected to extremes of temperature, humidity, and all types of air pollutants. For these reasons the

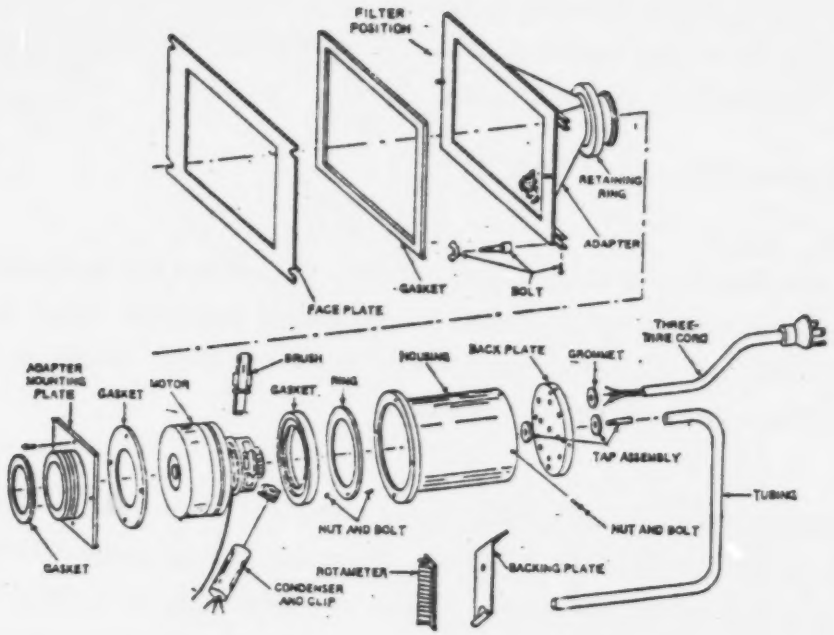

Figure A-1. Exploded view of typical high-volume air sampler parts.

materials of the shelter must be chosen carefully. Properly painted exterior plywood or heavy gage aluminum serve well. The sampler must be mounted vertically in the shelter so that the fiberglass filter is parallel with the ground. The shelter must be provided with a roof so that the filter is protected from precipitation and debris. The internal arrangement and configuration of a suitable shelter with a gable roof are shown in figure A-2. The clearance area between the main housing and the roof at its closest point should be 580.5 ± 193.5 cm^2 (90 ± 30 in.^{2}). The main housing should be rectangular, with dimensions of about 29 by 36 cm (11-1/2 by 14 in.).

5.1.3 Rotameter. A rotameter marked in arbitrary units, frequently 0 to 70, and capable of being calibrated is acceptable for measuring sample flow rates. Other devices of at least comparable accuracy may be used (see addendum A).

5.1.4 Orifice Calibration Unit. Consisting of a metal tube 7.6 cm (3 in.) ID and 15.9 cm (6-1/4 in.) long with a static pressure tap 5.1 cm (2 in.) from one end. See figure A-3. The tube end nearest the pressure tap is flanged

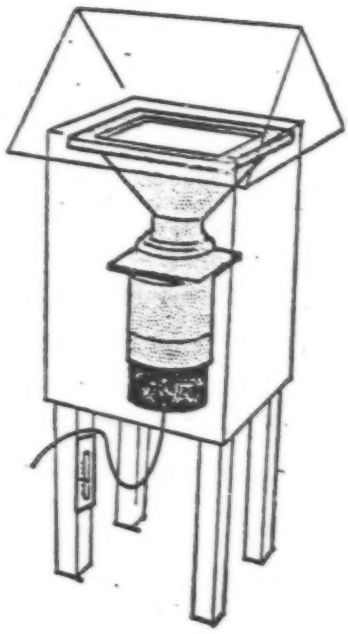

Figure A-2. Assembled sampler and shelter.

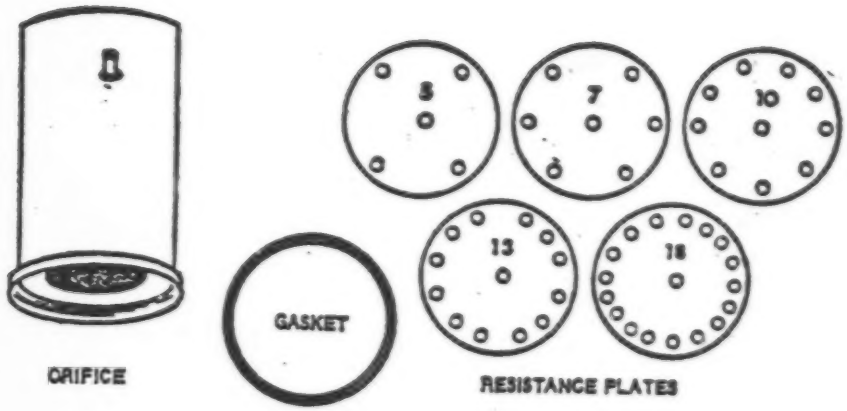

Figure A-3. Orifice calibration unit.

to about 10.8 cm (4-1/4 in.) OD with a male thread of the same size as the inlet end of the high-volume air sampler. A single metal plate 9.2 cm (3-5/8 in.) in diameter and 0.24 cm (3/32 in.) thick with a central orifice 2.9 cm (1-1/3 in.) in diameter is held in place at the air inlet end with a female threaded ring. The other end of the tube is flanged to hold a loose female threaded coupling, which screws onto the inlet of the sampler. An 18-hole metal plate, an integral part of the unit, is positioned between the orifice and sampler to simulate the resistance of a clean fiberglass filter. An orifice calibration unit is shown in figure A-3.

5.1.5 Differential Manometer. Capable of measuring to at least 40 cm (16 in.) of water.

5.1.6 Positive Displacement Meter. Calibrated in cubic meters or cubic feet, to be used as a primary standard.

5.1.7 Barometer. Capable of measuring atmospheric pressure to the nearest mm of Hg.

5.2 Analysis

5.2.1 Filter Conditioning Environment. Balance room or desiccator maintained at approximately 25°C and less than 10-percent relative humidity. A desiccator with fresh desiccant such as Drierite maintained in an air-conditioned room provides a satisfactory conditioning environment.

5.2.2 Analytical Balance. Equipped with a weighing chamber designed to handle unfolded 20.3 by 25.4 cm (8 by 10 in.) filters and having a sensitivity of 0.1 mg.

5.2.3 Light Source. Frequently a table of the type used to view X-ray films.

5.2.4 Number Device. Capable of printing identification numbers on the filters.

6.0 REAGENTS

6.1 Filter Media

Neutral fiberglass filters having a collection efficiency of at least 99 percent for particles of 0.3 μm diameter, as measured by the DOP test, are suitable for the quantitative measurement of concentrations of total suspended particulates (ref. 6), although some other medium, such as paper, may be desirable for

some analyses. If a more detailed analysis is contemplated, care must be exercised to use filters that contain low background concentrations of the pollutant being investigated. Careful quality control is required to determine background values of these pollutants.

7.0 PROCEDURE

7.1 Sampling

7.1.1 Filter Preparation. Expose each filter to the light source and inspect for pinholes, particles, or other imperfections. Filters with visible imperfections should not be used. A small brush is useful for removing particles. Print an identification number using the numbering device on the outer edge of the filters. Equilibrate the filters in the filter-conditioning environment (section 7.2) for 2 hours. Weigh the filters to the nearest 0.1 mg; record tare weight and filter identification number. Do not bend or fold the filter before collection of the sample.

7.1.2 Sample Collection. Open the shelter, loosen the wing nuts, and remove the faceplate from the filter holder. Install a numbered, preweighed, fiberglass filter in position (rough side up), replace the faceplate without disturbing the filter, and fasten securely. Undertightening will allow air leakage; overtightening will damage the sponge rubber faceplate gasket. A very light application of talcum powder may be used on the sponge rubber faceplate gasket to prevent the filter from sticking. During inclement weather the sampler may be removed to a protected area for filter change. Close the roof of the shelter, run the sampler for about 5 minutes, connect the rotameter to the nipple on the back of the sampler, and read the widest part of the rotameter float with the rotameter in a vertical position. Estimate to the nearest whole number. If the float is fluctuating rapidly, tip the rotameter and slowly straighten it until the float gives a constant reading. Disconnect the rotameter from the nipple; record the initial rotameter reading, the starting time, and the date on the filter or other suit ble form folder. (The rotameter should never be connected to the sampler except when the flow is being measured.) Sample for 4 hours and take a final rotameter reading. Record the final rotameter reading, ending time, and date on the filter folder or other suitable form. Remove the faceplate as described above and carefully

remove the filter from the holder, touching only the outer edges. Fold the filter lengthwise so that only surfaces with collected particulates are in contact, and place in a manila folder. Record on the folder or other suitable form the filter number, location, and any other factors, such as meteorological conditions or razing of nearby buildings, that might affect the results. If the sample is defective, void it at this time. In order to obtain a valid sample, the flow rate of a high-volume sampler must be measured with the same rotameter and tubing that were used during its calibration.

7.2 Analysis

Equilibrate the exposed filters for 2 hours in a low relative humidity (< 10 percent) and room temperature environment, then weigh to the nearest 0.1 mg. After they are weighed, the filters may be saved for detailed chemical analysis.

7.3 Maintenance

7.3.1 Sampler Motor. Replace brushes before they are worn to the point where motor damage can occur.

7.3.2 Faceplate Gasket. Replace when the margins of samples are no longer sharp. The gasket may be sealed to the faceplate with rubber cement or double-sided adhesive tape.

7.3.3 Rotameter. Clean as required, using alcohol.

8.0 CALIBRATION

8.1 Purpose

Since only a small portion of the total air sampled passes through the rotameter during measurement, the rotameter must be calibrated against actual airflow with the orifice calibration unit. Before the orifice calibration unit can be used to calibrate the rotameter, the orifice calibration unit itself must be calibrated against the positive displacement primary standard.

8.1.1 Orifice Calibration Unit. Attach the orifice calibration unit to the intake end of the positive displacement primary standard and attach a high-volume motor blower unit to the exhaust end of the primary standard. Connect one end of a differential manometer to the differential pressure tap of the

orifice calibration unit and leave the other end open to the atmosphere. Operate the high-volume motor blower unit so that a series of different, but constant, airflows (usually six) are obtained for definite time periods. Record the reading on the differential manometer at each airflow. The different constant airflows are obtained by placing a series of loadplates, one at a time, between the calibration unit and the primary standard. Placing the orifice before the inlet reduces the pressure at the inlet of the primary standard below atmospheric; therefore, a correction must be made for the increase in volume caused by this decreased inlet pressure. Attach one end of a second differential manometer to an inlet pressure tap of the primary standard and leave the other open to the atmosphere. During each of the constant airflow measurements made above, measure the true inlet pressure of the primary standard with this second differential manometer. Measure atmospheric pressure and temperature. Correct the measured air volume to true air volume as directed in subsection 9.1.1, then obtain true airflow rate, Q, as directed in subsection 9.1.3. Plot the differential manometer readings of the orifice unit versus Q.

8.1.2 High-volume Sampler. Assemble a high-volume sampler with a clean filter in place and run for at least 5 minutes. Attach a rotameter, read the float, adjust so that the float reads 65, and seal the adjusting mechanism so that it cannot be changed easily. Shut off motor, remove the filter, and attach the orifice calibration unit in its place. Operate the high-volume sampler at a series of different, but constant, airflows (usually six). Record the reading of the differential manometer on the orifice calibration unit and record the readings of the rotameter at each flow. Measure atmospheric pressure and temperature. Convert the differential manometer reading to m^3/min, Q, then plot rotameter reading versus Q.

8.1.3 Correction for Differences in Pressure or Temperature. See Addendum B.

9.0 CALCULATIONS

9.1 Calibration of Orifice

9.1.1 True Air Volume. Calculate the air volume measured by the positive displacement primary standard.

$$V_a = \frac{(P_a - P_m)}{P_a} \times (V_M)$$

where

V_a = True air volume at atmospheric pressure, m^3

P_a = Barometric pressure, mm Hg

P_m = Pressure drop at inlet of primary standard, mm Hg

V_M = Volume measured by primary standard, m^3.

9.1.2 Conversion Factors

Inches Hg × 25.4 = mm Hg.

Inches water × 73.48 × 10^{-3} = inches of Hg.

Cubic feet air × 0.0284 = cubic meters air.

9.1.3 True Airflow Rate

$$Q = \frac{V_a}{T}$$

where

Q = Flow rate, m^3/min

T = Time of flow, min.

9.2 Sample Volume

9.2.1 Flow Rate Conversion. Convert the initial and final rotameter readings to true airflow rate, Q, using the calibration curve of subsection 8.1.2.

9.2.2 Volume of Air Sampled. Calculate the volume of air sampled by

$$V = \frac{Q_i + Q_f}{2} \times T$$

where

V = Air volume sampled, m^3

Q_i = Initial airflow rate, m^3/min

Q_f = Final airflow rate, m^3/min

T = Sampling time, min.

9.3 Mass Concentration

Calculate mass concentration of total suspended particulates by

$$TSP = \frac{(W_f - W_i) \times 10^6}{V}$$

where

TSP = Mass concentration of total suspended particulates, $\mu g/m^3$
W_i = Initial weight of filter, g
W_f = Final weight of filter, g
V = Air volume sampled, m^3
10^6 = Conversion of g to µg.

10.1 REFERENCES

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2. G. P. Tierney and D. Conner. "Hygroscopic Effects on Weight Determinations of Particulates Collected on Glass-Fiber Filters." Am. Ind. Hyg. Assoc. J. 28 (1967): 363.
3. Robert M. Burton et al. "Field Evaluation of the High-volume Particle Fractionating Cascade Impactor--A Technique for Respirable Sampling." Presented at the 65th Annual Meeting of the Air Pollution Control Association, June 18-22, 1972.
4. Peter K. Mueller et al. "Selection of Filter Media: An Annotated Outline." Presented at the 13th Conference on Methods in Air Pollution and Industrial Hygiene Studies, University of California, Berkeley, California, October 30-31, 1972.
5. F. Smith and A. C. Nelson, Jr., "Guidelines for Development of Quality Assurance Programs and Procedures Applicable to Measuring Pollutants for Which National Ambient Air Quality Standards Have Been Promulgated," Final Report, Research Triangle Institute, Contract No. EPA-Durham-68-02-0598, Environmental Protection Agency, Research Triangle Park, N.C. 27711, August 1973.
6. J. B. Pate and E. C. Tabor. "Analytical Aspects of the Use of Glass-Fiber Filters for the Collection and Analysis of Atmospheric Particulate Matter." Am. Ind. Hyg. Assoc. J. 23 (1962): 144-50.

ADDENDA

A. ALTERNATIVE EQUIPMENT

A modification of the high-volume sampler incorporating a method for recording the actual airflow over the entire sampling period has been described, and is acceptable for measuring the concentration of total suspended particulates (J. S. Henderson. Eighth Conference on Methods in Air Pollution and Industrial Hygiene Studies, Oakland, Calif. 1967). This modification consists of an exhaust orifice meter assembly connected through a transducer to a system for continuously recording airflow on a circular chart. The volume of air sampled is calculated by the following equation:

$$V = Q \times T$$

Q = Average sampling rate, m^3/min.

T = Sampling time, minutes.

The average sampling rate, Q, is determined from the recorder chart by estimation if the flow rate does not vary more than 0.11 m^3/min. (4 ft^3/min) during the sampling period. If the flow rate does vary more than 0.11 m^3 (4 ft^3/min) during the sampling period, read the flow rate from the chart at 2-hour intervals and take the average.

B. PRESSURE AND TEMPERATURE CORRECTIONS

If the pressure or temperature during high-volume sampler calibration is substantially different from the pressure or temperature during orifice calibration, a correction of the flow rate, Q, may be required. If the pressures differ by no more than 15 percent and the temperatures differ by no more than 100 percent (°C), the error in the uncorrected flow rate will be no more than 15 percent. If necessary, obtain the corrected flow rate as directed below. This correction applies only to orifice meters having a constant orifice coefficient. The coefficient for the calibrating orifice described in 5.1.4 has been shown experimentally to be constant over the normal operating range of the high-volume sampler (0.6 to 2.2 m^3/min; 20 to 78 ft^3/min). Calculate corrected flow rate:

$$Q_2 = Q_1 \left[\frac{T_2 P_1}{T_1 P_2} \right]^{1/2}$$

where

Q_2 = Corrected flow rate, m^3/min

Q_1 = Flow rate during high-volume sampler calibration (subsection 8.1.2), m^3/min

T_1 = Absolute temperature during orifice unit calibration (subsection 8.1.1), K or °R

P_1 = Barometric pressure during orifice unit calibration (subsection 8.1.1), mm. Hg.

T_2 = Absolute temperature during high-volume sampler calibration (subsection 8.1.2), K or °R.

P_2 = Barometric pressure during high-volume sampler calibration (subsection 8.1.2), mm. Hg.

APPENDIX B

EXAMPLE CALCULATIONS

Example Data Sheet

TABLE 1
SIMULATED TSP DATA FOR CANDIDATE AND
REFERENCE HI-VOL METHODS

X = TSP $\mu g/m^3$ Measured by Reference Hi-Vol Method	Y =TSP Response Measured by Candidate Method
459	357
419	392
375	311
334	281
310	240
305	287
309	259
319	233
304	231
273	237
204	209
245	161
209	199
189	152
137	115
114	112

Example: Basic Worksheet Showing the Calculation Steps

Y denotes Candidate Method Response, X denotes Reference Hi-Vol Responses ($\mu g/m^3$)

a) ΣX = Sum of X
= 4505

b) $\overline{X} = \Sigma X/n$ = Average of X
= 282

c) n = Number of Test Pairs
= 16

d) ΣY = Sum of Y
= 3776

e) $\overline{Y} = \Sigma y/n$ = Average of Y
= 236

Step (1) ΣXY = Sum of X times Y
= 1,170,731

Step (2) $(\Sigma X)(\Sigma Y)/n$
= 1,063,180

Step (3) $S_{xy} = \Sigma (X - \overline{X})(Y - \overline{Y})$, $\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}$
Step (1) - Step (2)
= 107,551

Step (4) ΣX^2 = Sum of Each X Squared
= 1,404,543

Step (5) $(\Sigma X)^2/n = a^2/c$
= 1,268,439

Step (6) $S_{xx} = \Sigma (X - \overline{X})^2$ = Step (4) - Step (5)
= 136,104

Step (7) ΣY^2 = Sum of Each Y Squared
= 985,740

Step (8) $(\Sigma Y)^2/n = d^2/c$
= 891,136

Step (9) $S_{yy} = \Sigma (Y - \overline{Y})^2$ = Step (7) - Step (8)
= 94,604

Step (10) $Z = \frac{S_{xy}}{S_{xx}}$ = Slope of the Regression Curve

= Step (3) ÷ Step (6)

= 107,551/136,104 = .79

Step (11) $I = \bar{Y} - Z\,\bar{X}$ = Y intercept

= e - Step (10)b

= 236 - .79 (282) = 13.2

Step (12) r = Correlation Coefficient

$S_{xx} = \Sigma(X - \bar{X})^2$; $S_{yy} = \Sigma(Y - \bar{Y})^2$; $S_{xy} = \Sigma(X - \bar{X})(Y - \bar{Y})$;

$r = S_{xy}/\sqrt{S_{xx}}\sqrt{S_{yy}}$

= Step (3)/[Step (6)]$^{1/2}$ [Step (9)]$^{1/2}$

= 107,551/[136104.]$^{1/2}$ [94604]$^{1/2}$

= .95

Step (13) Method for Displaying Relationship

(a) Equation of Regression Line

$Y = I + ZX$

$Y = 13.2 + .79\ X$

(b) To predict the reference Hi-vol Method Value from the actual value obtained by the candidate method, use

$X = (Y - I)/Z$

For example let y - 240 (units)

(c) $X = (240 - 13.2)/.79$

$X = 287\ \mu g/m^3$